Agriculture and Agri-Food Canada
Research Branch

Agriculture et Agroalimentaire Canada
Direction générale de la recherche

Investing in life's basic building blocks

to secure Canada's future food supply

Canadian Crop Genomics Initiative

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Research Branch
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Technical Bulletin 1998-7E
Catalog No. A54-8/1998-7E ISBN 0-662-27130-0
August 1998

available from
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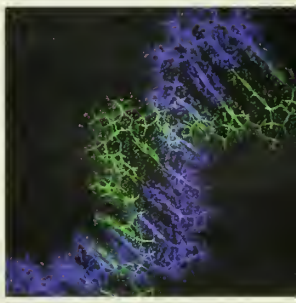
Introduction

All living animals and plants have genes that control the fundamental processes of life. Most genes are organized in physical structures called chromosomes. Genomics is the area of science that deals with understanding the structure, function, and interrelationships of the genes contained in living organisms. Some of the benefits that may result from an improved understanding of the structure and function of genes include

- more effective diagnosis and treatment of diseases in humans and crops
- new crops that are more nutritious and higher yielding
- reduced requirements for pesticides and fertilizers in food production.



Genomics will lead to the development of crops that can be used to produce a wide range of industrial, nutraceutical, and pharmaceutical products.

Recent advances in our capability to do genomics research are regarded as the most important new tools we have to meet the future needs of the planet for food. The hugely expanded ability to clone genes and study their function provides possibilities for improving the performance of crops that are of strategic importance to this country.

Canada needs to develop and sustain a leading position in this area of discovery, to secure a strategic interest in the development of superior crops for Canadian agriculture. Genomics research offers a rare opportunity for Canadians to

- reduce our reliance on pesticides and fertilizers for food production
- make the business of food production more sustainable and environmentally friendly
- ensure a safe and affordable food supply for the future

- contribute to value-added processing opportunities for the sector
- ensure that we remain globally competitive in the crops that we have a comparative advantage in growing
- strengthen Canada's position as a leading country for research and development in plant biotechnology
- create and retain high technology jobs at home.

This document outlines a framework for a coordinated and highly focussed Canadian Crop Genomics Initiative to be lead by the Research Branch of Agriculture and Agri-Food Canada (AAFC). Recent advances in genomics research technologies, including processes for automating many of the steps in gene identification, promise to greatly accelerate the process of assigning functions to genes.

This initiative aims to identify the structure and function of important genes. The work lays the basis for the development of future Canadian crops that

- are resistant to diseases and insects
- can better withstand stresses such as cold and heat
- have better yield and quality attributes.

Another benefit will be new platform technologies that will preserve the freedom to operate for a broad base of Canadian industries and public-sector institutions so that they can bring the products of their biotechnology innovations to the market in support of the Canadian agri-food sector.

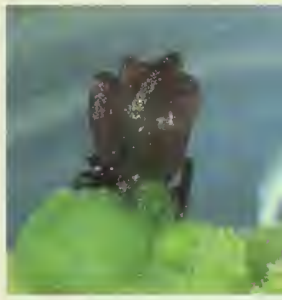
The 18 specialized centres of the Research Branch of Agriculture and Agri-Food Canada have a wide range of expertise in plant biology that is essential if the process of gene discovery is to extend to genes of true agricultural importance. AAFC expertise includes

- molecular biology
- bioinformatics

- entomology
- pathology
- crop physiology
- weed science
- natural products chemistry
- crop breeding
- genetics.

This integrated expertise is essential to

- finding useful genes
- understanding their function
- incorporating them into germplasm and crop varieties for the benefit of the Canadian agri-food industry.



There is a clear strategic opportunity for Canada to build on its historic strength in plant breeding and plant biology in this era of gene discovery. Targeted funding for key infrastructure developments and key biological resources at selected centres within the Research Branch of AAFC, allied with more widely distributed funding to selected centres of expertise in universities and the private sector for biology-driven gene identification and crop enhancement projects, would constitute a highly competitive Canadian Crop Genomics Initiative.

These highly focussed activities in agricultural crop genomics complement other genomics research proposals under consideration from the National Research Council (NRC) and the Medical Research Council (MRC).

Background: Consultation findings for the renewal of the Canadian Biotechnology Strategy

The sixth report (1998) of the National Biotechnology Advisory Committee entitled *Leading in the Next Millennium* recommended that

- Canada should continue to lead in biopharmaceuticals and agricultural biotechnology; and the federal government should advance postgenomic studies through increased funding to Canada's genome program with strong emphasis on functional genomics, bioinformatics, proteomics, domain studies, and differential gene expression.

The Canadian Agricultural Research Council conducted consultations this spring in support of the development of the Canadian Biotechnology Strategy. In a report entitled *Opportunities and Challenges for Application of Biotechnology in the Canadian Agri-Food Sector,* it recommended that

- public institutions play a leadership role in a number of basic areas of research, including genomic technologies for specific projects of relevance to Canada's major agricultural commodities and for increased R&D in support of agri-food regulation. The report also emphasized the principle of building on strengths and previous investments.

Parliament's Standing Committee on Agriculture and Agri-Food held a set of meetings this spring, also in support of the development of the Canadian Biotechnology Strategy. In a report (1998) entitled

Capturing the Advantage: Agricultural Biotechnology in the New Millennium, it recommended that

- funding for long-term basic research within AAFC be increased. Special mention was made of projects of major international potential and of research to build on Canadian strengths and commercial possibilities through partnerships.

The Medical Research Council's Genome Task Force in a report (1998) entitled *Genomics: A Platform for the New Century* concluded that

- genomics is one of the most important emerging fields of scientific research, promising enormous benefits for quality of life, wealth creation, and sustainable development with consequences for every branch of life science: human health, agriculture, fisheries, forestry, and more.

The National Research Council in an independent report (1998) entitled *Genome Sciences Strategic Initiative* concludes that

- genomics will have a major impact on the development of new plant varieties, the manipulation of plant genetic traits, and the production of new tools for monitoring and managing biodiversity.

Taken together the reports conclude:

- genomics is the opportunity of the coming century and is of pivotal importance to many sectors; the reality is that many important genes for critical human needs will soon be discovered and patented using advanced genomics tools, and Canada must be a player
- research in the area of genomics needs to be funded
- there is a need for multidisciplinary approaches
- many opportunities are cross sectoral in nature
- both private and public institutions have significant roles to play.

The opportunity

Canadian potential to capture the benefits

- Canada's agri-food industry generates $44 billion annually in revenue. Total agri-food exports are $20 billion annually; of this, food products now account for $8 billion. The sector accounts for 15% of Canadian employment and 9% of our gross domestic product.

- As most of Canada's potentially arable land is currently in production, and because the sector receives few subsidies, Canada's capacity to meet the ever-expanding demand for more and better food products by a world with an estimated population of 8 billion by 2030 will depend on innovation increasingly involving biotechnology.

- Canadian economic activity surrounding agri-food biotechnology ($319 million) is second only to that of the pharmaceutical industry ($396 million). It is estimated that 26% of Canada's core biotechnology companies are in the agrifood sector. This biotech industry weighting, which is about fivefold that of the United States, provides an extremely strong rationale to accelerate Canadian agri-food biotechnology investment.

- About 20% of processed foods and beverages are produced utilizing the techniques of biotechnology; fermentation technologies have been particularly widely adopted.

- The developed world's aging demographics have generated exciting markets for functional food and nutraceutical products having health-promoting attributes. The National Institute of Nutrition recognizes the tremendous potential of biotechnology to enhance the nutritional qualities and health properties of food.

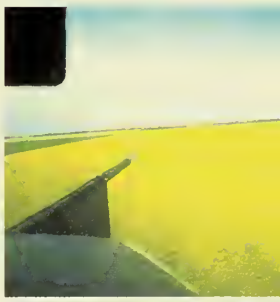
These functional foods point to the convergence of the agri-food and health industries.

- A cooperative approach involving the private sector, public research institutions, and government regulators has permitted the rapid adoption of crops with novel traits produced using biotechnology. For example, we estimate that transgenic varieties of canola will be grown on 50% of the crop's Canadian acreage in 1998. This represents a remarkable adoption rate, as such varieties only received their first interim registrations in 1995.

The targets

Farmed crops

- Canada is a globally important producer of crops. Currently we account for more than 5% of the world's production of wheat, barley, canola, flax, peas, and lentils. Much of this production is currently exported as bulk commodity.



- Wheat, barley, and canola exports amount to about 85% of Canada's bulk crop exports. Canada is a major producer of wheat and canola. Major benefits are expected to accrue to Canada from research to improve wheat and canola production efficiencies through enhanced insect and disease resistance and better tolerances to low temperature and drought. Improved processed quality and nutritional traits, as well as derived value-added products, will dramatically increase values. Research efforts in farmed crops will focus on wheat and canola. This means that successes will result in extremely meaningful benefits for Canada in terms of economic sustainability and the environment.

Marketable molecules

- Both plants and animals have been used as vehicles to produce high-value molecules for extremely diverse applications. For example, human therapeutic proteins including enzymes, antibodies, and vaccines have all been expressed in a range of plant species. Plants also have much potential for producing chemicals for industrial, food, and feed applications. Research Branch scientists are collaborators in such projects. For example, the microflora found in the rumen of cattle are being mined for beneficial genes. Collaborative projects in future would target products for the agri-food sector and chemicals of interest to other sectors. We expect that cooperative projects in future would rapidly evolve between the Human and Plant Genome program teams.

The receptor base for technologies

- Many multinational agricultural companies have an active R&D presence in Canada. Novaritis, DuPont, Monsanto, Pioneer Hi-Bred, Dow AgroScience, AgrEvo-PGS, Limagrain, Zeneca, DeKalb, and Svalof Weibul are examples. All are incorporating their biotechnology innovations into seeds that are sold to producers. Such mechanisms for technology dissemination are extremely efficient, as the adoption rate of herbicide-tolerant canola varieties proves.

- There are a considerable number of Canadian plant biotech startups (Performance Plants, Prairie Plants, SemBioSys, DNA Landmarks), in addition to Canadian seed companies.

- Private industry players are actively restructuring world wide in an effort to position themselves to capture emerging value chains that can be exploited by application of plant functional genomics.

Major organizations are vertically integrating to provide both commodity production input products (e.g. pest-resistant varieties) and to process novel trait crops into feeds, foods, and ingredients for markets world wide. These developments are expected to provide Canadians with many opportunities for technological innovation and commercial exploitation.

AAFC competency in plant science

- Research Branch has provided effective national leadership to the Canadian agri-food sector in scientific and technology development for more than 100 years. We have pursued gene discovery and exploitation research, and then delivered the results as technologies in finished products—commercial agricultural crop varieties. To accomplish this track record, Research Branch, through its network of 18 specialized centres strategically located near our clients and partners, has established comprehensive expertise in all the component scientific disciplines of plant science.

- Plant genomics relates to Research Branch business lines including genetic resources, crops, soil resources, animals, and value-added foods. All business lines incorporate biotechnology into their science and technology development projects.

- Research Branch has the extensive biological support essential for gene discovery and exploitation. This includes pathology, entomology, weed science, physiology, agronomy, chemistry, genetics, bioinformatics, and crop breeding.

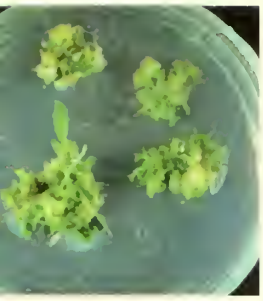
- Research Branch has already made a significant investment in genomics.

Some biotechnology applications in AAFC

- AAFC in partnership with industry led development and introduction of the first commercial transgenic oilseed variety in the world—Innovator Canola.

- Canada has internationally respected agricultural biotechnology regulations thanks to effective cooperation between the public and private sectors to resolve the issues by doing and applying the science.

- Breeding programs for field crops (barley, wheat, oats, canola, flax, and peas) have developed and implemented routine use of molecular and genomic tools such as doubled haploidy, genome maps, and gene (trait) markers (marker-assisted selection).



- Map-based gene cloning in wheat and canola is under way.

- Gene-expression studies (jointly with the Plant Biotechnology Institute of the NRC) have been established.

- Proprietary genes and gene promoters have been discovered related to carbohydrate metabolism and cold tolerance.

Linkages and partnerships

- Research Branch, consisting of 18 specialized centres having strong relationships with, and presence on or near major universities across Canada, would facilitate collaboration and stimulate human resource development.

- Through its Matching Investment Initiative Program, Research Branch has established strong working relationships with its industry partners and clients. The branch has developed considerable capability on business and legal aspects related to

the development, management, and exploitation of intellectual property.

- Research Branch has strong and longstanding working relationships with NRC and laboratories in Europe as well as with science establishments of the United States government. For example, with the NRC, Research Branch transformed an industrial oilseed into a new edible oil—canola; this was followed by herbicide-tolerant canola.

Proposed crop genomics initiative in relation to the overall Canadian genomics effort

- Because the global race to discover and patent genes from a wide array of species is now under way, AAFC recommends that government investment in biotechnology should build on existing strengths and foster complementary activities.

- AAFC supports many of the common principles enumerated in the NRC and MRC genomics proposals. Namely, an entity consisting of interested stakeholders should be created to facilitate the establishment of strategic alliances to develop "platform" genomic technologies and provide services to functional genomics initiatives in humans, plants (particularly in *Arabidopsis* and rice for application in Canadian crops), and possibly other appropriate organisms.

- Appropriate platform technologies and services could include

  - high-throughput DNA sequencing to support international efforts in sequencing the rice and *Arabidopsis* genomes
  - proteomics
  - bioinformatics
  - DNA (gene) chips.

- AAFC would work closely with NRC in the development and utilization of these platform technologies.

- AAFC believes that successful functional genomics initiatives, particularly those relating to expression of desirable agronomic traits and processed-product qualities, will depend on extensive and related competencies in molecular and quantitative genetics, physiology, pathology, and biochemistry of the relevant target organism. Groups leading the development of organism-specific functional genomics technologies should have demonstrated a broad capacity and be in a position to form partnerships and agreements with key groups across Canada, and world wide.

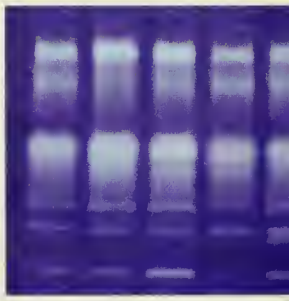
Research Branch led functional genomics initiative

- Based on the above-mentioned criteria, Research Branch is best positioned to lead functional genomics initiatives relating to economic plants within a "virtual" public research organization.

- The Initiative would be led and managed by Research Branch. Two integrated sets of collaborative multidisciplinary projects would be organized, incorporating scientific strengths wherever they might exist within Canada and as appropriate in other countries. One set would focus on *Arabidopsis* and canola and the other on rice and wheat.

- An essential element of the strategy would be to lever available data from global chromosome-sequencing programs in *Arabidopsis* and rice (and possibly other cereals) to target desirable genes for the sustainable development of Canada's agri-food sector, particularly those areas relating to canola and wheat.

- Plant genome projects would require close cooperation with "platform technology" initiatives within and outside of AAFC. Services and technologies needed would include high-throughput DNA sequencing, bioinformatics, DNA chips, and proteomics.



- To effectively utilize the gene discoveries from genomics research, this initiative must develop key enabling technologies such as promoters and plant transformation protocols to enable freedom to operate for a broad base of industry and public laboratories to commercialize the newly discovered genes controlling agriculturally useful traits.

- A major goal of the program is to commercialize genomic technologies involving plants. Because genomics research is expected to result in rapid gene discoveries, and hence to generate intellectual property, a major focus of the initiative will be to manage intellectual property in such a way as to create business opportunities that will stimulate establishment and growth of viable Canadian plant genomics companies.

- Research Branch will establish partnerships with MRC, NRC, universities, and the private sector to assemble the best possible teams for each project to accomplish objectives most effectively.

Program elements

While the appropriate core facilities and key biological resources are essential if the opportunities for accelerated gene discovery offered by modern genomics are to be realized, the success of a Canadian Crop Genomics Initiative will ultimately depend on

- the ability of biologists to detect differences in plant phenotype, e.g. pathologists detecting changed disease reactions, physiologists detecting enhanced cold acclimation, or chemists measuring changes in seed quality
- the imagination and ingenuity of scientists in converting information about gene activity into enhanced crop performance.

For this reason, the main component of the proposed Canadian Crop Genomics Initiative will be a coordinated set of targeted and biology-driven projects lead by AAFC scientists who have the most relevant scientific expertise.

The projects will be targeted to the crop systems with

- the best short-term potential for rapid gene discovery
- the best long-term potential for generating economic benefits from enhanced performance.

The projects will also be targeted to

- traits of strategic importance to Canada
- traits in which Canadian science is likely to maintain an international lead.

The biology-driven projects will include five main types of activities:

- gene discovery
- comparative biology
- developing new technologies (in both molecular biology and informatics)
- map-based gene cloning
- crop modification.

This program will incorporate Canada's historic strength in plant breeding and plant biology into a genomics-based gene discovery initiative. The program will involve targeted funding for developing key infrastructure and biological resources, and for biology-driven projects for gene identification and crop enhancement.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Infrastructure

- Infrastructure investments will be made to automate gene discovery.

- The minimum physical infrastructure needed to support Canadian crop genomics research is high-capacity DNA sequencing (with bioinformatics analysis) and facilities for generating and screening DNA chips and microarrays. Together, these facilities will generate the molecular data that makes it possible to automate some aspects of gene discovery.

- Two types of biological resources are central to the process of accelerating gene cloning and gene discovery for wheat and canola. These resources are ordered genome libraries and gene-tagging populations.

- Ordered large-insert libraries of genomic clones (ordered genome libraries) automate the process of map-based gene cloning and are of great use in comparative biology and in the

identification of duplicate genes. Ordered genome libraries also facilitate the isolation of the chromosome segments corresponding to expressed sequence tagging and thus gene-engineering and promoter investigations.

- Gene-tagging populations can be used to discover the functions of genes through reverse genetics. At present, this process involves inserting gene-disrupting elements at random into a plant genome and using the polymerase chain reaction technique to identify plants with insertions in particular genes. The characteristics of these mutated plants are then investigated. A whole library of such plants can now be developed, in which each plant has a disrupting element inserted into a different gene and in which the genomic DNA sequence of each mutagenic insertion point has been determined and catalogued. With this type of population, computers can be used to identify the plant that has a mutation in a gene of interest. The identified plant can then be subjected to exhaustive analysis to identify even very subtle changes in phenotype.

Targeting Canadian traits

- **Cold and heat tolerance and freezing resistance** are important characteristics for almost all crops and are of crucial strategic importance to Canada. Freezing resistance has a significant bearing on yield stability and cold tolerance (particularly as it relates to the vigor of seedling growth) and has a major influence on yield potential. Parallel gene discovery programs in different systems will likely uncover novel and complementary avenues to engineering increased cold tolerance and increased frost resistance.

- **Resistance to disease** is an important characteristic in all crops. Many pathogens are specific to particular crops, and the economic importance of different pathogens often varies with

geographical region. For these reasons, genes involved in mechanisms for disease resistance must be given a high priority by the Canadian Crop Genomics Initiative. There are also many similarities between the mechanisms that plants use to detect and respond to different pathogens. These similarities will provide useful points of contact and information exchange between scientists working on different systems.

- **Seed quality** is a major component of all cereals, pulses, and oilseed crops. The genes that control seed development, carbon partitioning, protein quality, oil quality, starch quality, and the accumulation of antinutritional compounds will be major targets for discovery and modification by the Canadian Crop Genomics Initiative.

- **Resistance to insects** is important for reducing crop losses and pesticide use. Canada's major crops are affected by a variety of insects, such as flea beetles in canola and wheat midge. Molecular biologists and entomologists will examine and develop a molecular basis for both antibiotic and antixenotic approaches to insect resistance. Germplasm and varieties will be developed with resistance to economically important insects.

Budget

The budget estimate for a globally competitive initiative in plant genomics involves an investment of $25 million annually over a 10-year period.

Appendix

Biotechnology research and expertise within AAFC

AAFC has significant biotechnology expertise in eight of its 18 research centres across Canada. Each centre has a specialized mandate to build on the agricultural strengths of the region. Coordinated programs across centres create a strong national capability. A brief description of biotechnology research in AAFC follows.

Pacific Agricultural Research Centre, Summerland

The research program focuses on

- development of agronomic traits for tree fruit, small fruit, and vegetable crops
- protection against plant pathogens, including fungi, viruses and bacteria, and insects
- processing, utilization, and quality of plant products.

Scientists have been working on

- molecular control of enzymatic browning in pear and apple
- resistance to numerous diseases (e.g. fire blight, scab, powdery mildew) using transgenes
- genomic mapping and gene isolation in apple
- marker-assisted selection for self fertility in cherry
- control of biological systems that regulate fruit flavor, texture, and color
- transgene-based virus resistance
- DNA-based diagnostics for viruses, bacteria, and fungi

- gene mapping and cloning in fungi and bacteria
- risk assessment for recombination between transgene viral sequences and the actual virus
- modification of viruses and fungi as biocontrol agents.

The centre is well connected to the horticultural industry and the research community, nationally and internationally.

Lethbridge Research Centre

The centre conducts biotechnology research on ruminant animals and potatoes. Results include

- enzymes isolated from rumen microorganisms involved in digestion of complex carbohydrates and proteins
- expression systems developed for producing enzymes (xylanases, cellulases, phytases, proteases) that originate from rumen microorganisms as components of fodder plants and as feed additives for nonruminant animals
- microbes identified that produce bacteriocins and bioactive peptides for control of rumen microflora
- biotechnology used in potato for germplasm identification, studies of genetic inheritance, germplasm development, and identification of DNA markers
- detection systems developed for several fungal and viral pathogens (*Fusarium*, potato leafroll virus, tobacco rattle virus)
- DNA markers identified for resistance to *Verticillium*.

The centre has strong connections to the beef and potato industries.

Saskatoon Research Centre

The major focus of the centre is on canola development. The program has a large molecular genetics group, and sections on

- ecological crop protection
- oilseed breeding
- natural products chemistry
- sustainable land management.

The centre has an active program of germplasm development for *Brassica napus*, *B. rapa*, and the related species *B. juncea*, *B. carinata*, and *Sinapis alba*. The capacity for germplasm development is a major resource for biotechnology research and development.

Targets for crop improvement are

- resistance to insects (phytochemicals, protease inhibitors)
- cold tolerance (modifying low-temperature growth characteristics and controlling cold acclimatisation)
- resistance to pathogens (*Leptosphaeria*, *Sclerotinia* - designing resistance genes, pyramiding resistance genes, interspecific transfer of genes)
- oil quality
- meal quality
- increasing yield capability (new hybrid systems and reduced pod shatter)
- drought and heat tolerance.

The centre has new laboratories designed especially for biotechnology and genomics research, with facilities for

- developing large insect libraries of genomic clones for map-based gene cloning

- sequencing (for developing expressed sequence tags and microsatellite markers)
- systems for controlling gene expression
- marker-assisted selection of complex plant genotypes
- mathematical modeling
- bioinformatics.

The centre has a good working relationship with the National Research Council's Plant Biotechnology Institute. It enjoys a long tradition of close cooperation with all segments of the oilseed industry and is strongly supported by the Canola Council of Canada. The main laboratory building is ideally situated for collaboration with private sector partners in research and development, including the major domestic and multinational agrochemical and seed companies, who have research laboratories at Innovation Place, adjacent to the University of Saskatchewan.

Cereal Research Centre, Winnipeg

The centre is the national centre of specialization for cereal crops and is internationally recognized for its work on hard red spring wheat and flax. It has one of the best collections world wide of genetic resources on wheat, barley, and flax. The program utilizes marker-assisted selection for

- high protein content
- heavy metal uptake
- disease resistance (*Fusarium*, stem and leaf rust, tan spot)
- insect resistance (wheat midge)
- weathering resistance.

Genome mapping has been used for an array of traits affecting end-use quality. All registered Canadian wheat varieties have been DNA fingerprinted. Gene cloning has been practised for specific proteins that affect milling and baking quality (glutenins) and disease

resistance. The centre has a strong tradition in host–parasite physiology and in developing cultivars with superior quality. It is a logical extension to apply the tools of genomics for a better understanding of the interactions between pathogens and plants, as well as manipulating genes that affect quality components in the seed. The program has a highly effective integration of the molecular biology team with plant breeders, pathologists, entomologists, and cereal chemists.

The centre has close working relationships with several private sector partners for the development of

- hybrid wheats
- end use quality traits (storage proteins, modifying starch synthesis, industrial enzymes)
- antifungal proteins
- agronomic traits (lodging resistance, sprouting resistance, herbicide resistance).

The centre, located on the University of Manitoba campus, has good working relationships with the

- grain industry
- Canadian Wheat Board
- Canadian Grain Commission
- Western Grain Research Foundation
- Keystone Agriculture Producers
- other organisations.

Eastern Cereal and Oilseed Research Centre, Ottawa

The program has responsibility for variety development for corn, soybean, wheat, barley, and oats for Eastern Canada. It has one of the largest and longest operating plant biotechnology groups in Canada. The centre has expertise in molecular strategies for

- gene expression (promoters, transacting factors)
- insect resistance
- cold tolerance
- seed protein modification
- host–pathogen interaction
- seed coat modification
- control of development (fertility).

The biotechnology group is closely integrated with scientists working on variety development. Specific projects include

- resistance to *Fusarium* in corn and wheat
- resistance to *Sclerotinia* and *Phytophthora* in soybean
- transformation technologies
- constitutive and tissue-specific promoters
- cold tolerance in corn and soybean
- marker-assisted selection for disease resistance and end use traits in oats, barley, wheat, and soybean
- expressed sequence tags in soybean
- mapping of the oat genome.

The centre has a history of strong working relationships with large private-sector companies and is strongly supported by small seed companies based in Ontario and Quebec, Secan, and the Ontario Field Crops Research coalition.

Southern Crop Protection and Food Research Centre, London

The program focuses on the development of

- environmentally friendly systems for the protection of fruit, vegetable, ornamental, and field crops against insect and plant pathogens
- alternate crops for the coarse-textured soils of southern Ontario.

Current biotechnology projects include

- production of pharmaceutical products (vaccines for diseases of swine, immune modulators for treatment of diabetes) using tobacco and other plant species
- expressed sequence tags in stevia (a plant grown for production of low-calorie sweetener)
- isolation of seed-coat-specific genes in soybean
- mapping and cloning of genes for resistance to *Phytophthora*
- diagnostics for fungi, based on polymerase chain reaction
- molecular genetics of pathogenicity in *Verticillium*
- isolation and characterization of microbial agents for bioremediation of soils
- characterization of virulence genes in the bacterial tomato pathogens *Xanthomonas campestris* and *Pseudomonas syringae*
- isolation of tumorigenesis-suppressing genes from *Agrobacterium vitis* (crown gall in grape)
- *Bacillus thuringiensis* resistance in corn borer
- plant transformation systems for stevia and other potential new crops
- resistance to fire blight in pear.

The centre is located in the heart of an area of intensive horticultural production. Protection research is aimed at gaining a fundamental understanding of the interaction between pest and host. The ultimate objective is to develop superior control technologies.

Soils and Crops Research and Development Centre, Sainte-Foy

The centre concentrates on developing forage crops and sustainable production systems. Current projects in biotechnology work on developing alfalfa cultivars with superior winter survival. Molecular probes and restricted fragment length polymorphism markers are developed for genes whose low-temperature expression is related to improved survival. Marker-assisted selection is developed for a number of fungal and bacterial pathogens (*Phytophthora, Aphanomyces, Verticillium, Fusarium, Corynebacterium*). A more novel project conducted in collaboration with firms in the pharmaceutical industry involves producing large amounts of high-value pharmaceutical proteins using transgenic alfalfa plants.

The centre is closely linked to Laval University, MAPAQ, Coop Federée, UPA, and the seed industry.

Potato Research Centre, Fredericton

The centre mandate includes

- potato breeding
- a national repository of potato genetic resources
- potato pest management, physiology, and soil and water management.

Biotechnology projects include the development or characterization of

- DNA markers for sugar content and dormancy
- a promoter for processing quality traits
- genes related to sugar metabolism and dormancy
- DNA level information for genetic combining ability of a parent or line
- a viral promoter for a number of pathogens

- genes related to late blight, common scab, and viruses from *Solanum* sp.
- rt-polymerase chain reaction technology for potato virus and viroid detection.

The centre is closely linked to major Canadian potato processors (McCains, Cavendish Farms), as well as to the seed trade. About 50% of seed potatoes exported from Canada are grown in close proximity to the centre.

Other centres

In addition to these eight centres, there are 10 other AAFC centres of specialization across Canada. Each uses the tools of biotechnology in carrying out its research program and is part of a mechanism to develop the products of biotechnology to the stage of technology transfer to the agricultural industry.

- The centres at Swift Current, Brandon, and Harrow use doubled haploids and marker-assisted selection in developing durum wheat, specialty wheats, barley, and soybean.
- The centres at Saint-Jean-sur-Richelieu, Charlottetown, and Lacombe have expertise in developing systems for control of disease, insects, and weeds.
- The centres at Kentville and St-John's develop cultivars of small fruits (blueberry, strawberry, and lingonberry) and apples.
- The centres at Saint-Hyacinthe and Lacombe work on food issues from bio-ingredients to novel products, packaging, and preservation.

Collectively, the 18 centres represent a strong network for developing and delivering technology to the Canadian agri-food industry.


Lacombe
Saskatoon
Summerland
Lethbridge
Swift Current
Brandon
Winnipeg
St.-John's
Charlottetown
Ste-Foy
Fredericton
Kentville
St.-Hyacinthe
Lennoxville
Ottawa
St.-Jean
London
Harrow


Canada